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Doctoral Dissertation  
Physics Department  
Portland State University  
1997

Student: David S. Silver

Title : Surface Studies of Metals after Interaction with Hydrogen Isotopes

Presented : November 7, 1997

**Results :** " A cold rolled single crystal palladium cathode was electrolyzed in a solution of D<sub>2</sub>O and 15% H<sub>2</sub>SO<sub>4</sub> by volume for 12 minutes. The cathode bent toward the anode during electrolysis. Examination of both concave and convex surfaces using the scanning electron microscope (SEM), scanning tunneling microscope (STM), and atomic force microscope (AFM) revealed rimmed craters with faceted crystals inside and multi-textured surfaces. Also pairs of cold rolled polycrystalline palladium cathodes underwent electrolysis for six minutes in D<sub>2</sub>O and H<sub>2</sub>O solutions, each solution containing 15% H<sub>2</sub>SO<sub>4</sub> by volume. Surface morphologies of the heavy water electrolyzed samples revealed asperities, craters, and nodules, and evidence of recrystallization and crystal planes. After 1.5 years, new AFM studies of the same Pd surfaces exposed to heavy water electrolyte exhibited loose, nanometer-sized particles. However, the surfaces of Pd cathodes exposed to light water electrolyte remained nearly identical to morphologies of foils not electrolyzed, and did not change with time. Secondary ion mass spectrometry (SIMS) determined the concentrations of the stable six palladium isotopes. A six minute heavy water electrolyzed sample showed inversions of Pd<sup>108</sup> with Pd<sup>106</sup> and Pd<sup>110</sup> with Pd<sup>104</sup>, which deviate from their natural abundance. These results support claims made by Fleischmann and Pons that nuclear transformations occur during electrolysis of Pd cathodes in heavy water solutions ".

Approved by the examining committee:

John Dash, Chair, Professor of Physics  
Makoto Takeo, Professor Emeritus of Physics  
Pavel Smejtek, Professor of Physics  
Reinhart Engelmann, Professor of Physics, Oregon Graduate Institute  
Robert O'Brien, Professor of Chemistry

Doctoral program approval :

James Pratt, Director, Environmental Sciences and Resources Ph.D. Program

**EXHIBIT A**

Doctoral Dissertation  
Physics Department  
Portland State University  
2001

Student : Jon Warner

Title : Interaction of Titanium with Hydrogen Isotopes

Presented : December 5, 2001

Results : "Using two different calorimeter systems ( 8-cell and Seebeck Envelope Calorimeter ( SEC )), 64 electrolytic cells were run in 29 experiments. Of the 64 experimental cells, 38% showed evidence of excess heat generation overall. Excess heat was not claimed until the power output was at least 100 mW greater than power input which is  $5\sigma$  above the typical 8-cell error level and  $10\sigma$  above the typical SEC error level.

Elemental changes were explored using a Scanning Electron Microscope (SEM) with an attached Energy Dispersive Spectrometer (EDS), a Focused Ion Beam (FIB) with a Secondary Ion Mass Spectrometer (SIMS), a Transmission Electron Microscope (TEM), Neutron Activation Analysis (NAA), and X-Ray Diffraction techniques (XRD). Of the 64 experimental cathodes, 38% were analyzed both before and after electrolysis using SEM and EDS techniques. The results of these analyses have shown that 50% of the excess heat producing cells displayed evidence for Cr and 36% of the non-excess heat producing cells exhibited evidence for Cr as well as other elements. Chromium was also found using NAA and FIB/SIMS techniques."

"The amounts of heat output are generally large compared to the known chemical reactions taking place inside the cell. For example, in the "Discussion" chapter we showed an excess heat output of  $152,000 \pm 13,000$  J where the net heat increase due to the known chemical reactions taking place in the cell under electrolysis is 318 J".

Approved by the examining committee :

John Dash, Chair, Professor Emeritus of Physics  
Pavel Smejtek, Professor of Physics  
Monica Halka, Assistant Professor of Physics  
Mingdi Yan, Assistant Professor of Chemistry  
Robert O'Brien, Professor of Chemistry

Doctoral program approval :

Roy Koch, Director, Environmental Sciences and Resources Ph.D. Program

Master of Science Theses  
Physics Department  
Portland State University  
1990 – 2002

**Topic: Interaction of Hydrogen Isotopes with Metals**

**Student : Patrick S. Keefe**

**Title: Comparison of Light and Heavy Water Electrolysis with Palladium Cathodes**

**Presented : July 26, 1990**

**Results : “ Excess energy in the form of heat was observed in the heavy water cell. A tritium increase of 51% occurred in the heavy water cell of Experiment One. Microscope studies of a palladium cathode showed internal rupture after electrolysis of heavy water, but there was no such damage to the palladium from the light water electrolysis ”.**

**Approved by the examining committee:**

**John Dash, Chair, Professor of Physics  
Erik Bodegom, Professor of Physics  
Jack Semura, Professor of Physics  
Robert O'Brien, Professor of Chemistry**

**Departmental approval:**

**Mark Gurevitch, Professor and Chair, Department of Physics**

**Student : Grant L. Noble**

**Title: Morphology and Microanalysis of Palladium Cathodes after Electrolysis in Light and Heavy Water**

**Presented : September 19, 1992**

**Results: “ Highly localized gold was found in one area, of high current density, on each cathode. The gold most certainly came either from the concentration of gold as an impurity in the palladium or from transmutation. Gold is completely miscible in palladium and should not concentrate ”.**

**Approved by the examining committee:**

**John Dash, Chair, Professor of Physics  
Laird Brodie, Professor of Physics**

**Robert O'Brien, Professor of Chemistry**

**Departmental approval :**

**Erik Bodegom, Professor and Chair, Department of Physics**

**”**

**Student : Christoph Zaczek**

**Title : Electrolysis of Palladium in Heavy Water**

**Presented : July 3, 1995**

**Results : " No evidence for fusion, or any other nuclear reaction in the crystal lattice of palladium, used as cathode in heavy water electrolysis, was observed ".**

**Approved by the examining committee :**

**John Dash, Chair, Professor of Physics**

**Laird Brodie, Professor of Physics**

**Robert O'Brien, Professor of Chemistry**

**Departmental approval :**

**Erik Bodegom, Professor and Chair, Department of Physics**

**Student: Radovan Kopecek**

**Title : Electrolysis of Titanium in Heavy Water**

**Presented : June 29, 1995**

**Results : " It appears that excess heat is produced during electrolysis of heavy water with a titanium cathode. The amount of this excess heat was 750 cal in a one hour period, an energy gain of 44%. No significant emission of any of the products associated with a " classical " deuterium-deuterium fusion was observed during either experiment, i.e. heat but no radiation. Unexpected elements were found in both experiments, i.e. K, Cr, Fe, Ni, and Zn".**

**Approved by the examining committee:**

**John Dash, Chair, Professor of Physics**

**Erik Bodegom, Professor of Physics**

**Robert O'Brien, Professor of Chemistry**

**Departmental approval :**

**Erik Bodegom, Professor and Chair, Department of Physics**

**Student : Jon Warner**

**Title : Observations of Heat Produced and Chemical Changes Caused by Electrolysis of Titanium with Heavy Water**

**Presented : October 26, 1998**

**Results : " Excess heat was found in three of the eight experimental cells with a range of 0.13 +/- 0.08 to 0.23 +/- 0.08 watts, where 0.08 watts is three standard deviations".**

**" The unexpected elements found on C3E3 were S, K, Ca, V, Cr, Fe Cu, Ni. After ultrasonically cleaning C3E3 for 30 seconds another analysis was made using the SEM and EDS. It was found that V, Cr, Fe, Ni remained ".**

**Approved by the examining committee :**

**John Dash, Chair, Professor Emeritus of Physics**

**Pavel Smejtek, Professor of Physics**

**Robert O'Brien, Professor of Chemistry**

**Departmental approval:**

**Erik Bodegom, Professor and Chair, Department of Physics**

**Student : Gregory R. Goddard**

**Title : Characterization of Uranium Co-Deposited with Hydrogen on Nickel Cathodes**

**Presented : January 10, 2001**

**Results : " Effects were seen in all of the experiments. These effects included increased radiation output, anomalous presence of iron, and changes in the gamma energy spectrum of the electroplated compound as compared to the solid residue remaining after evaporation of the liquid from unelectrolyzed solution ".**

**Approved by the examining committee :**

**John Dash, Chair, Professor Emeritus of Physics**

**Lee Casperson, Professor of Electrical and Computer Engineering**

**Rudi Nussbaum, Professor Emeritus of Physics**

**Robert O'Brien, Professor of Chemistry**

**Departmental approval :**

Erik Bodegom, Professor and Chair, Department of Physics

Student : Conrado Salas Cano

Title : Comparison of Heat Output and Microchemical Changes of Palladium Cathodes under Electrolysis in Acidified Light and Heavy Water

Presented : July 8, 2002

Results : " In the second experiment, the D<sub>2</sub>O cell produced an excess heat relative to the H<sub>2</sub>O cell that was too large by at least an order of magnitude to be explainable by chemical reactions or mechanical artifacts ".

" After electrolysis, it was found that Cd was present on the surface of the H<sub>2</sub>O cathode at levels of concentration that were variable but generally no less than 4% relative to Pd (above 3 sigma) ".

" On this D<sub>2</sub>O cell cathode, no statistically significant traces of Cd were detected but Ag was present in 2-5% concentration relative to Pd. In some spots, the Ag abundance surpassed 20% that of Pd. The most likely explanation is neutron-induced nuclear transmutation of some of the Pd nuclides with direct release of heat into the solid state lattice".

Approved by the examining committee:

John Dash, Chair, Professor Emeritus of Physics

Pavel Smejtek, Professor of Physics

Robert O'Brien, Professor of Chemistry

Departmental approval :

Erik Bodegom, Professor and Chair, Department of Physics